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FABRICATION AND APPLICATION OF A STANDARDIZED T1/T2 MOUNT

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Experimental impact forces which affect the cervical spine are accurately reflected at T1 and consequently can be measured there. Adventitious movement of an acceleration measuring system at T1 can distort data and thereby diminish the validity of conclusions drawn from that data. A standardized T1/T2 mount has been fabricated and used to improve the study of human response to experimental impact. Gross slippage has not been evident since adopting the new mount and strapping techniques.

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The animals used in this work were handled in accordance with the principles outlined in the "Guide for the Care and Use of Laboratory Animals (National Institutes of Health Document No. NIH 80-23)," established by the Institute of Laboratory Animal Resources, National Research Council.

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FABRICATION AND APPLICATION
OF A STANDARDIZED T1/T2 MOUNT

INTRODUCTION

Human response to impact is studied at the Naval Biodynamics Laboratory (NAVBIODYNLAB) using a horizontal accelerator which propels a restrained subject in a sled along an indoor track. Similar research using a vertical accelerator will begin in the near future at the Laboratory. Experimental impact forces which affect the cervical spine and head are accurately reflected at the subject's first thoracic vertebra (T1), and consequently can be measured there.

A system to measure acceleration at T1 has been developed which consists of: (1) an anatomical mount molded from each subject's cervicothoracic region; (2) a fixture which is fastened to the mount and held to the subject by straps; and (3) a plate carrying accelerometers and photo targets which is attached to the fixture. Unfortunately, kinematic measurements from this instrument package reflect not only T1 motion, but also any adventitious movement of the package.

Since the anatomical mount can not be rigidly attached to T1 (e.g., surgically attached to the spinous process of T1), there has been concern about whether the instrument package accurately follows T1 motion. Review of cinephotography has shown occasional package movement relative to T1 depending on the input force and the coupling between the package and the subject. Adventitious mount movement can create distortions in the force input/acceleration output relationship between T1 and the cervical spine and head. As a result, mathematical models designed to represent dynamic head and neck interaction and manikins which are based on this data may be less reliable in certain vectors.

Since beginning human impact experiments in 1973, the NAVBIODYNLAB staff has attempted to design an anatomical mount which minimizes adventitious movement. A shearless T1 mount which could be strapped to a specific and repeatable surface location on a subject's upper back was specially designed.[1] The goal was to design a mount which would follow T1 motion regardless of changes occurring in torso configuration and strap length during acceleration.

Procedures to apply the mount were outlined in detail in 1985.[2] Later, a study of the effect of mount slippage on various T1 acceleration components was completed.[3] T1 accelerations were taken from a Hybrid III dummy with a rigidly attached mount and compared with one in which the mount was merely strapped. Minimal differences were seen in the X linear acceleration component (the primary driver of head motion), but all other components had spurious oscillations which indicated some motion relative to T1.

Since then, a series of seven human runs in the -X direction have been analyzed and spurious oscillations and/or spikes were identified in some less significant components. Moreover, during a recent human +Z series, data analysis, film review, and pre- and post-run photographs of skin impressions made by the mount evidenced sporadic slippage.

Further measures, therefore, were indicated to control cervicothoracic mount slippage. A study comparing the dynamic responses of three different geometries showed that the best data reproducibility was exhibited by a mount overlying the spinous processes of both T1 and T2.[4] The fabrication and application of a standardized T1/T2 mount is outlined below.

FABRICATION

Until 1976, the NAVBIODYNLAB's thoracic mounts were fabricated using traditional fiberglass techniques. An impression was lifted from a subject's spine with a mixture of dental plaster, chopped fiberglass strands, polyester resin, and a hardener. After this impression cured, a second one was taken from it as a positive form upon which a mount with excellent structural integrity and biofidelity was made. This method required a craftsman from outside the Laboratory and was eventually abandoned. In 1976, the Laboratory adopted a method which used fiberglass orthopedic cast material which hardened when exposed to ultraviolet light. Unfortunately, this fiberglass material became unavailable in 1985 and a new fabrication method was required.

The latest method, which is similar to the original three-step fiberglass technique, yields a thoracic mount of improved biofidelity by making a greater surface contact with the skin overlying T1 and T2. The new method can be divided into two procedures: modeling and construction.

A. Modeling

(1) Using a felt tip pen, mark the subject's skin overlying the spinous processes of C7, T1, and T2 (Figure 1). The spinous processes are best identified with the subject seated on a stool, head flexed, and arms hanging loosely at the sides.

(2) Apply a lubricant to aid in the separation of the impression from the subject's skin. Common hand lotion serves as a good releasing agent.

(3) Mix children's modeling clay and mineral oil in a ratio of one cubic inch of clay to one drop of oil.

(4) Press this mixture, in a container 4" long x 3" wide x 1/2" deep, over the area from C7 - T2. The entire area must be covered and adequate pressure must be applied (Figure 2).

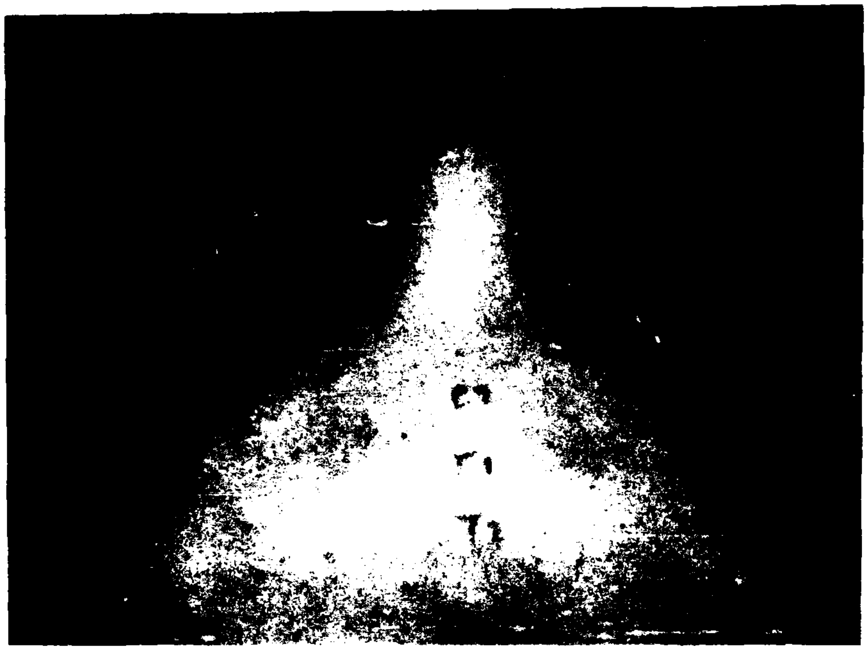

FIGURE 1 - Skin overlying subject's C7, T1, and T2 spinous processes appropriately marked for modeling.

FIGURE 2 - Impression being taken from subject's cervicothoracic region.

(5) Place the impression in a freezer for one hour.

(6) Remove the impression, in its container, from the freezer and fill the container to the top with Plaster of Paris. Allow the plaster to dry for approximately 24 hours.

B. Construction

(1) After the plaster model is dry, examine it for holes or bumps caused by the drying process. These defects should be filled or sanded to conform to the subject's surface anatomy.

(2) Thinly coat the surface to be fiberglassed with a standard mold releasing agent.

(3) After the releasing agent is dried, apply enough coats of white gelcoat (1 to 3) to the entire top surface (surface contacting the spinous processes) of the model to obtain a 1/32" thickness.

(4) When the gelcoat is cured, the mount can be constructed according to the dimensions in Figure 3.

APPLICATION

High speed cinephotography and data analysis of impact runs have indicated that the thoracic mount occasionally tends to move away from T1 upon abrupt neck flexion. This movement varies unpredictably between runs. In 1985, an experiment was conducted to determine if the movement resulted from variability in mount strapping tightness. The investigators found that excessive, inadequate, or uneven strap tightening resulted in a poor tracking of the mount to T1 motion. Therefore, developing a standard strapping procedure has been considered a crucial part controlling mount slippage.

Due to anatomical variation between subjects, a formal strapping procedure presents difficulty. Nonetheless, adherence to certain steps can minimize adventitious mount movement during a run.

(1) Before moving to the sled (and before attaching straps and instrumentation to the mount), position the T1/T2 mount properly on the subject's back. The spinous processes in the cervicothoracic region are best identified with the subject seated on a stool, head flexed, and arms hanging. Using a felt tip pen, trace an outline of the upper border of the mount onto the subject's skin. This mark will aid in placing the mount properly when the subject is on the sled.

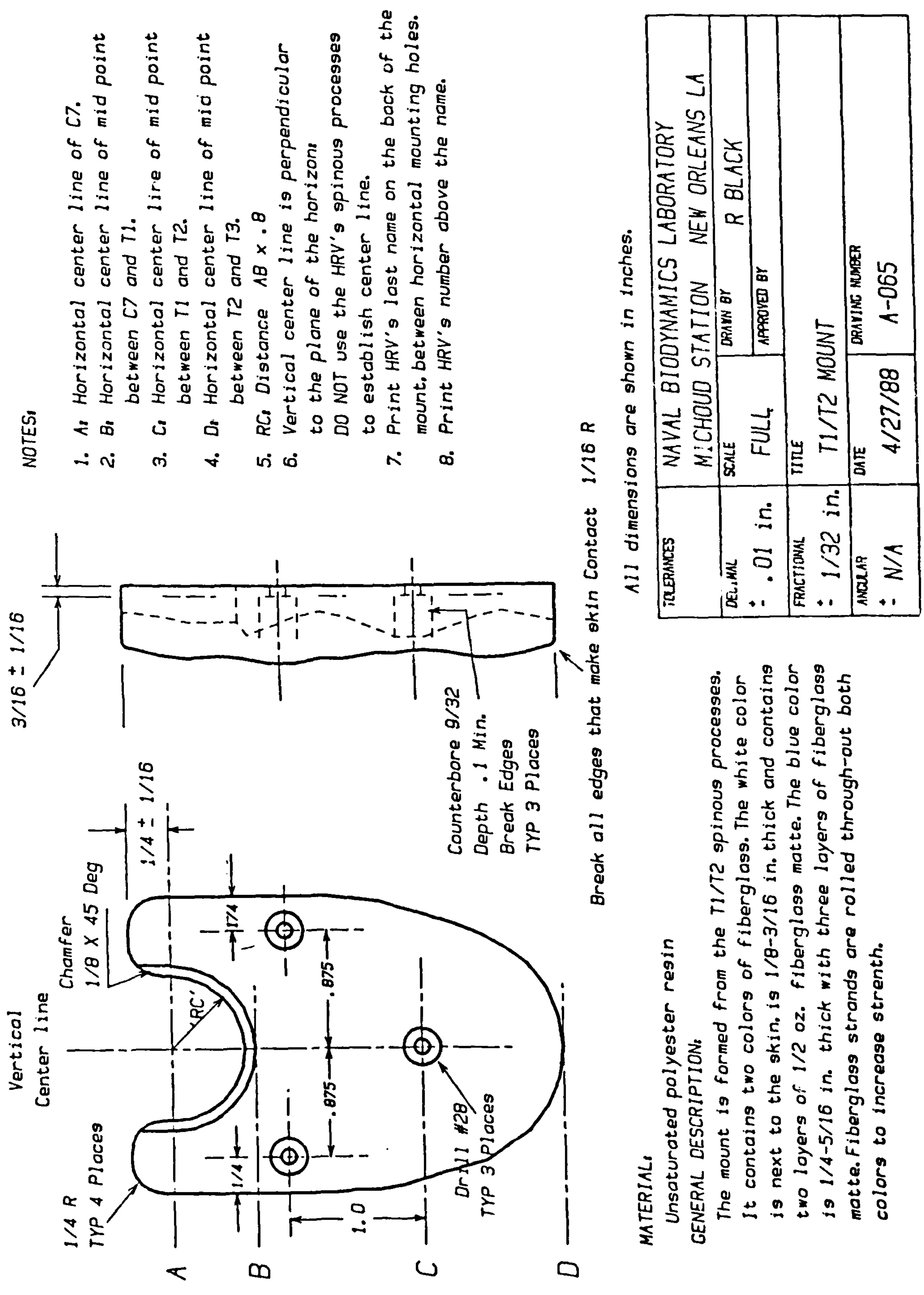

FIGURE 3 - Schematic drawing of standardized T1/T2 mount.

(2) After the subject is in the sled's restraint system and has flexed his neck, place the T1/T2 mount into proper position. Hold the mount firmly in position and begin tightening all four straps. Continue to tighten the straps with the subject's neck in a neutral or slightly flexed position. The front straps should be substantially tighter than the rear ones when this step is completed.

(3) A simple check can be performed to assess the adequacy of the strapping. Pull the subject back into the seat with the restraints and ask him to flex his neck. If the T1/T2 mount does not pull away from the skin or otherwise alter its position, strapping is satisfactory. If the mount does pull away or change position, the restraints are released and step 2 is repeated.

CONCLUSION

Since adopting the standardized T1/T2 mount and strapping procedure, gross slippage as reflected by either distorted skin impressions or data with obvious artifacts has not been seen. Nevertheless, certain concerns have been expressed about the T1/T2 mount.

A criticism has been made that the T1/T2 mount measures T1/T2 motion rather than purely T1. A second objection has been raised that splinting by the mount may effect T1 motion itself. The benefit of reducing adventitious mount movement using an increased area of skin contact, however, greatly outweighs these potential disadvantages. Moreover, it is doubtful that a mathematical model will be developed which will require differentiating between T1 motion and T1/T2 motion.

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